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AVIATION AND AERONAUTICAL ENGINEERING

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VOLUME VIII
Number 7

Three Dollars a Year

SPECIAL FEATURES

THE ORENCO TYPE F TOURISTER
MOLYBDENUM STEELS
THE PIONEER TURN INDICATOR
THE JUNKERS ARMORED TWO-SEATER BIPLANE
VIBRATION OF SPARS IN AIRCRAFT

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MAY 1, 1920

AVIATION AND AERONAUTICAL ENGINEERING

VOL. VIII NO. 7

Member of the Audit Bureau of Circulations

INDEX TO CONTENTS

THE GARDNER, MOFFAT COMPANY, Inc., *Publishers*

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ISSUED ON THE FIRST AND FIFTEENTH OF EACH MONTH FORMS CLOSE FIVE DAYS PREVIOUSLY APPLICATION FOR ENTRY AS SECOND CLASS MATTER AT THE POST OFFICE AT HIGHLAND N. Y., PENDING

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AVIATION
AND
AERONAUTICAL ENGINEERING

ALEXANDER KLEMIN TECHNICAL EDITOR
LADISLAS d'ORCY ASSOCIATE EDITOR
GEORGE NEWBOLD BUSINESS MANAGER

Vol. VIII May 1, 1920 No. 7

IN considering the possibility of an American machine entering for the Gordon-Bennett Cup Race, American designers have been discouraged by the fact that no American air-cooled engines of large power are available.

Whether this is indeed a serious drawback, is a question of some doubt. While a large air-cooled engine gives the designer high power for light weight, its projected area and the resistance of projecting parts is very considerable. Furthermore its ability to maintain its rated maximum power for any considerable period of time is questionable.

It seems quite possible that a clever design, round the small, easily streamlined Wright-Hispano, or the Curtiss C-12, would, while looking poorer on paper, offer a very good chance of success.

Gasoline Connections

In the earlier stages of the entry of the United States in the war, a well known training plane fell into considerable disrepute. Though sturdily constructed and with good flying properties, its disrepute was due to engine failure, and a certain well built four cylinder engine came in for the greater share of the blame and general popular disfavor. Many well informed pilots and mechanics are of the opinion, however, that neither the general design of the plane, nor yet the engine, were responsible for the difficulties, but simply a poor engine installation and poor gasoline connections.

Gasoline connections responsible for endless troubles and serious accidents present a situation which should never occur again, and it is for this reason that some recent experiments by the Army Air Service on gasoline connections are of considerable value, which is still enhanced by the fact that a definite conclusion is given as the result.

The most suitable type of flexible connection for a gasoline line is one made of high grade rubber, resistant to the action of gasoline and provided with a metallic nipple between the ends of the pipes to be joined in order to prevent rubber from flaking into the gasoline line.

Definite information of this character on essential details is perhaps of greater value to the industry than the most profound and exhaustive aerodynamical researches.

The Use of Duralumin

Considerable interest is at the present moment exhibited in the use of duralumin in airplane structures. Designers lay particular stress on German and British achievements in this direction, and also emphasize the fact that the specific tensile strength of duralumin is so high. On the other hand, surprise is expressed in some quarters at the fact that duralumin is being employed to so small an extent, and that wood is still used for the most part.

To these contentions it may be replied that constructors may find that duralumin is not quite as promising as at first appears to be the case. To begin with, the sources of supply in this country are very limited. Then, the material obtained is not yet of uniform quality and is still subject to considerable variation in both tensile strength and elastic modulus. The width of sheet that can be rolled is also limited. Neither welding or soldering being possible with duralumin, the problem of small rivets is a very serious one, both from the point of view of production costs and security in manufacture. The drilling of a hole may soften the duralumin. The rivet which does not fill up its hole completely, may be a serious cause of danger under vibration. Finally the cost of working duralumin parts in small quantities is certain to be far greater than that of wooden parts.

It will be thus seen that the use of duralumin in aviation involves some very serious problems, several of which have not as yet found their solution in a manner authorizing the employment of this alloy in current airplane construction.

Airship Engines

In a recent paper before the Royal Aeronautical Society of Great Britain the lecturer emphasized the fact that airship engines have peculiarities of their own and that engines which are perfectly satisfactory for other services are not necessarily suitable for airship work.

Yet, the special requirements which Major C. F. Abell indicated for the airship engine apply with almost equal force to the airplane engine for use on the commercial airplane.

The advocacy of a single line engine of six cylinders, as giving greater accessibility and a simplified exhaust piping, would be equally sound for an airplane engine, and a six cylinder vertical engine finds much favor among airplane designers.

The cylinders should be made separately and should be interchangeable. Surely nothing more pleasing could be provided for operation in the field. The valves of airship engines should, according to the same authority, be fitted in the head of the cylinders and operated by overhead rockers, so that timing is not interfered with by the removal of a cylinder; this differs in no way from the consensus of opinion regarding airplane engines.

Inspection doors in the upper half of the crank-case, large enough to allow pistons and connecting rods to be removed without disturbing the cylinders, are an ideal feature especially where cylinders are at all hard to remove.

Magnetos should all be arranged to rotate in the same direction to simplify the carrying of spares. General accessibility is considered highly desirable. A dry sump is advocated for the lubrication system.

The paper confirms altogether an opinion often voiced namely, that the airship engine will not be fundamentally different from the airplane engine. While for military purposes weight limitations are rather more important for the airplane than for the airship in commercial aviation, the airplane engine will inevitably progress on the lines of greater reliability and is more likely to approach the somewhat greater weight of the airship engine.

The Orenco Type F Tourister Airplane

Flight tests of the Orenco type F tourist plane have given proof that the design is most satisfactory for cross-country touring and passenger carrying. The type F is the first commercial design of the Ordnance Engineering Corp.; heretofore the aircraft department of the company has been exclusively engaged in supplying airplanes to the United States government, but while still building late types of military aircraft, the success of its first commercial plane serves as an encouraging beginning for the series of original sport and commercial types now under consideration.

When the type F plane was exhibited at the New York Aero Show in March, some doubt was expressed as to whether the 150 hp engine would be sufficient for a four-seater plane with side-by-side seating. The plane was first tested with pilot alone and found to possess marked stability, quick climb and plenty of reserve power. Further tests were then made with one, two and three passengers, and in each case the same even stability and sensitive response to controls was observable. In one test with four aboard, and full fuel load, the plane rose from the ground after a run of about 200 ft. On another test with three aboard, the plane was flown at full speed parallel to the ground at a height of only a few feet and although a gusty wind was blowing at about 25 m.p.h., the plane kept an even straight course, necessitating practically no movement of controls.

There are no controls in the forward seat and the two front passengers have ample room. In the rear cockpit the dual side-by-side controls allow either of the two occupants to handle the plane. The control arrangement is well suited for instruction, for the pilot is close to his pupil who can see just what the pilot does throughout the flight. The close proximity of instructor and pupil makes vocal comment possible, thereby doing away with the sign language instruction method.

Specifications

PERFORMANCES

Number of seats	Four
Engine Wright Hispano model A	150 hp
Weight	
Empty	1477 lb
Fully loaded	2432 lb
Useful load	865 lb
Fuel weight	238 lb
Range at full speed	250 miles
Speed	
Near ground	92 m.p.h.
at 5,000 feet	84 m.p.h.
at 10,000 feet	78 m.p.h.
Climb	
in 5,000 ft	9 min
in 10,000 ft	24 min
in 15,000 ft	60 min

Loading	
per horsepower	16.2 lb.
per square foot	7.10 lb.

DIMENSIONS

Span	
Upper wing	38 ft.
Lower wing	36 ft.
Wing chord both planes	5 ft.
Overall length	26 ft. 10 in.
Overall height	8 ft. 5 in.
Gap between wings	60 in.
Stagger	10 in.

AREAS

Wing areas	
Upper	183 sq. ft.
Lower	172 sq. ft.
Total (with ailerons)	355 sq. ft.
Aileron area	41.5 sq. ft.
Vertical areas	
Fin	4.30 sq. ft.
Rudder	6.6 sq. ft.
Horizontal areas	
Stabilizer	29.7 sq. ft.
Elevators	21.6 sq. ft.

Main Planes

The R. A. F. No. 15 wing curve is used. The wing chord is 5 ft. and the span of both upper and lower wings, 38 ft. The wings are built in four main panels in addition to the center panel which is 44 in. wide. Upper and lower panels are similar in all respects. The gap between wings is 5 ft., dihedral, upper and lower, 1.5 deg., incidence, 2 deg.

Ribs are built up with grooved spruce battens and basswood webs lightened between spars. All ribs are identical throughout and are equally spaced 12 in. apart. Internal compression members between spars are square section spruce, tapered. Internal wiring is with solid No. 10 wires and turnbuckles. Drift wires are doubled in two inner bays, while anti-drift wires are single.

The leading edge is of semi-oval section spruce. The spars are of spruce, channelled to I section between compression and wing struts. The trailing edge is of light Shelby steel tube, attached to the ribs with sheet copper strips. The wing ends are of laminated spruce. Balsa wood is used to round out curves where strength is not required, and mahogany veneer 1-16 in. thick is employed on top of wings from leading edge to front spar. Flat head brass nails are used throughout. All wood parts are coated with Valspar varnish to protect them from moisture; metal fittings and wires are enamelled to prevent corrosion.

Best grade A Irish linen is used for wing covering. The fabric is sewed on and bound with protective tape in the approved manner. After three coats of dope, the wings are varnished and enamel applied in any desired color. Valentine's special grey is used unless otherwise specified.

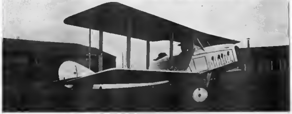


FIG 1. THREE-QUARTER FRONT VIEW OF THE ORENCO TOURISTER

FIG 2. THREE-QUARTER REAR VIEW OF THE ORENCO

Wing Trussing

The interplane struts are all similar in shape with the exception of a variation in length to provide for the difference in gap between front and rear spars. The maximum strut section is 1½ in. by 4½ in. Upper ends of center section struts are 3 ft. 4 in. apart. Intermediate struts are located 7 ft. 5 in. from center line of plane, from these the outer struts are spaced 8 ft., leaving an overhang of 3 ft. 8 in.

The strut fittings consist of an eye bolt running through the cable plate and wing beam, another bolt running through the plate-fitting close to the incidence cable does not pierce the beam. The struts have a sheet steel plate fitting with a slot to receive the eye-bolt. This fitting allows an adjustment of the stagger.

All cables are 5-32 in. in diameter; flying cables are doubled.

Incidence cables are eliminated in the center section trussing, so that easy access to the front cockpit is facilitated. Drift and anti-drift stresses are taken care of by a pair of inclined steel tube struts running from the center section to the fuselage. These tubes have solid steel adjustable forked ends and are faired with balsa wood, wrapped with linen. Four drift cables run from the lower longerons, aft of radiator, to the ends of the rear intermediate wing struts.

Fuselage

The length of the fuselage, from radiator face to stern-post, is 21 ft. 5 in.; maximum depth, 3 ft. 8 in.; width at cockpits, 3 ft. 8 in. The centerline of propeller shaft is 12.8 in. below the top of upper longerons, to which it is parallel. At the stern, the fuselage terminates in with a 14 in. steel tube.

When in normal flight position, the top longerons are 8 ft. 8 in. from the ground, in this position a line from wheels to skid makes an angle of 12 deg. with the ground line.

The longerons are 1¼ in. square ash from the radiator to the rear of the cockpit, 1¼ in. spruce aft of rear seat. Cross and vertical members are of spruce, cross tied with solid piano wire, No. 8 forward of pilots seat, No. 10 aft. At the rear they are all tapered from 1¼ in. square at center to ⅞ in. at ends.

Aluminum cowls, No. 20 gauge, surround the fuselage at the cockpits and from radiator to front center panel struts. Ventilating louvres are set about 3 in. apart. Aluminum faces the fuselage on the under side from front to rear chassis members, but elsewhere grade A linen covering is used. All aluminum coverings in the region of the engine are provided with inspection doors and are attached with easily removable thumb screws, drilled and locked with copper "safety" wire.

A turtle deck is built up of light spruce T section longitudinal members, supported on lightened veneer diaphragms. The deck is easily detached for adjustment or inspection of the internal fuselage wiring.

Control cable openings in the body are protected by heavy pig-skin slots stitched to the linen fabric. To facilitate handling, hand holes are provided on the lower longerons forward of the stabilizer.

The radiator is supported on the sheet-steel engine plate. Engine bearers of laminated ash are supported on the engine plate and two veneer bulkheads. Steel tube braces are run from points near the lower longerons at station 3 to front end of engine bed, and also from station 2 to lower edge of engine plate.

Seating Arrangement

Two passengers are accomodated in the front seats, are of mahogany birch-mahogany veneer. Separate cushions are provided for seats and backs. The safety belt straps are carried down by means of a steel ribbon to one of the heavy longitudinal members near the lower longerons. A continuous aluminum fire wall separates the engine section from the front cockpit. A locker located between top longerons and the curved cowling will hold about 2.5 cu. ft. of contents.

The floor is of three-ply veneer and rests directly on the lower longerons. It is secured to the latter by lightened transverse stringers strengthened on the underside by longitudinal members to which the rudder foot bar pyramids are bolted.

Wind shields of transparent celluloid are built up with aluminum frames. The rear shield is designed so as to permit unrestricted vision over the sides in making landings.

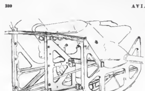
Instruments

The mahogany instrument board is fitted with a tachometer indicating up to 2000 r.p.m., a Taylor Instrument Company's Altimeter with zero mark adjustable with sea level, and indicating up to 25,000 ft., an 8-day Waltham watch, and oil gauge and a Boyce distance-type thermometer for engine water temperature. All instruments have "radium" dials. The throttle control lever is at center of the instrument board so it may be operated from either right or left seat. The carburetor altitude adjustment lever is at the right hand longeron.

For starting, a Dixie Type 800 magneto is used. It is of the same construction as the larger magnetos and is mounted in front of the pilot's instrument board. The engine is primed through the pet cocks on the intake manifolds and turned over compression on about three cylinders by the propeller. The mechanician stands aside and the pilot puts the ignition switch on and turns the starting magneto by hand. This gives a shower of sparks into one of the running magnetos and is transmitted through the carbon brush to the spark plug of the particular cylinder the engine happens to be stopped on. This starts the engine if the mixture is correct and all other things properly set.

Landing Chassis

The wheel tread is 5 ft. 5 in. and the wheels 26 in. by 4 in. The axle is 1½ in. in diameter with 3-16 in. wall. The axle is located 1 in. aft of the lower wing leading edge. The chas-



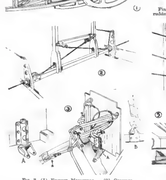


FIG. 3. (1) ENGINE MOUNTING (2) CONTROL ARRANGEMENT (3) TAIL SKID ARRANGEMENT

six members are of spruce, 5.6 in. by 1.5 in. and of streamline section. The upper ends are secured to the body by means of double forked plate fittings with longitudinal pins. Shock absorber cord is attached to saddle fittings outside the chassis members, giving a maximum of impact absorption close to the wheels.

Double cables, with spruce fillers between, brace the forward chassis struts; there are no cables aft.

Two steel tubes space the lower ends of the chassis. A balsa wood streamline fairs in the spacing tubes. This streamline unit is 9 in. by 4 ft.; it has some of the properties of a wing and does not add to the head resistance.

Controls

Two control sticks and foot bars are provided in the rear cockpit. The control column and the members are of square steel tube. The transverse shaft with steel levers for elevators is carried on bronze bearings at either side of the cockpit. The vertical columns have forked lower ends. A spacer bar is run between the columns about 3 in. above the transverse shaft. The aileron cables terminate at the spacer bar ends. The cables run direct to guide pulleys which lead the cables through the transverse shaft bearings, from which point the cables emerge from the body. The cables run around pulleys at outer wing struts and then up to upper ailerons.

A steel tube bar, streamlined with balsa wood, connects upper and lower ailerons. The compensating aileron cable runs from the lower ailerons to pulley at upper wing and then across the underside of upper wing. Turnbuckles are provided for adjustment at the center section. Fibre guides on the wing struts prevent wear and whipping of the cables.

The elevator cables run direct from control stick levers to the steel control arms on the elevators. A pair of rudder cables are run independently from each foot bar, using four cables in all. Fibre cable guides are bolted on the under side of pilot's seat.

Tail Group

Fin and rudder are built up with steel tube frames. The rudder ribs are of light gauge channelled sheet steel, drilled for lightness, all wrapped and welded to the frame. The fin base measures 3 ft.-5 in.; the height, 2 ft.-9in. The fin sternpost is of a steel tube which continues down and fits into the steel tube fuselage termination. Tube braces run from the stabilizer to points 9 in. from the top of the fin. Maximum dimensions of the rudder are height, 4 ft.-6 in.; width, 2 ft. 9 in.

The stabilizer is bolted to the upper longerons with ½ deg. incidence angle and is built up like the wings, with spruce ribs. The overall span, at rear edge, is 10 ft.; the chord, 3 ft.-4 in. It is supported from below by means of steel braces at its forward main beam and solid wires at the rear. The elevators are 2 ft.-8 in. wide and measure 10 ft. 10 in. from tip to tip.

Tail Skid

The ash tail skid is mounted on a universal fork bearing. Its upper ends are tied with ⅜ in. rubber cord, which is anchored to steel rings running through the upper portion of the solid veneer bulkhead at the station nearest the stern-post. A steel cable limits the stretch of the rudder and a single length of rudder cord in the lower longerons absorbs the rebound motion. Rawhide lacing is used to tie the rudder cords together. The lower end of the skid is shod with a substantial metal shoe.

Because of the difficulties encountered by tail skids, special research was made to obtain a really efficacious skid and this design has proven exceptionally satisfactory in all its details.

Engine Group

The engine is an 8-cyl. model A Wright-Hispano, developing 150 hp. at 1450 r.p.m. at sea level.

Bore and stroke is 120 mm by 130 mm; the displacement, 11,762.15 cu. in. The weight of the engine complete with hub-flange and bolts, carburetor and two magnetos, but without radiator, oil, starting magneto, propeller or fuel system is 445 lb.

A Zenith type 48 D C carburetor is used. Air is led to the carburetor by means of a megaphone duct behind the water radiator. The mixture proportion delivered by the Zenith is subject to a slight variation in passing from sea level to about 3,000 ft. altitude. By moving the altitude adjustment lever at the side of cockpit, the mixture can be corrected for about 10,000 ft. altitude.

The gasoline consumption is 13 to 15 gal. per hr. at 1450 r.p.m. and the oil consumption, ¾ gal. per hr. The main fuel tank is under the front seat and has a capacity of 27 gal.; a gravity tank is mounted in the center section and holds 8 gal. The oil tank is below the flooring of the forward cockpit, its capacity is about 4 gal.

A propeller-driven gear pump on the right hand chassis member pumps fuel from the main tank to the gravity tank. A copper feed pipe with shut-off valve leads fuel to the carburetor jet. Overflow line run down the two rear center section struts; glass sight gauges indicate whether the system is functioning properly. A "Sasco" strainer located on the lower right hand longeron, under the pilot's floor is interposed in the gasoline system between main tank and gear pump, to keep the fuel free from foreign matter.

A Hartzell walnut propeller, 8 ft. 9 in. in diameter, is used with blades wrapped with linen from tips to within 18 in. of the center.

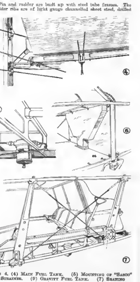


FIG. 4. (4) MAIN FUEL TANK. (5) MOUNTING OF "SASCO" STRAINER. (9) GRAVITY FUEL TANK. (7) SEATING ARRANGEMENT

Molybdenum Steels

The physical and dynamic properties of the different Molybdenum steels, together with the characteristics developed by varying heat treatments, are comprehensively treated in the catalogue of the Climax Molybdenum Company.

The catalogue constitutes apparently a very reliable metallurgical study of these new alloys, and the makers claim with some show of reasonableness that the steels are not too expensive, in view of the savings possible in weight and labor by its use.

Molybdenum owes its name to the word "Molybdaena," under which title most minerals resembling lead in appearance were known in the eighteenth century. It is a metallic element reduced chiefly from the sulphide molybdenite (MoS_2), which is a mineral very similar in appearance to graphite. Molybdenite and other Molybdenum bearing ores are found widely distributed throughout the world.

The metal (Mo) resembles platinum in general physical appearance, although it is darker and possesses a peculiar lustre. Its atomic weight is 96, its specific gravity about 9, its specific heat about .07, and it melts at about 2,550 deg. Cent. Despite the very high melting point of metallic Molybdenum, it alloys readily with iron, the ferro-molybdenum having a melting point of approximately 1,470 deg. Cent. It resists most acids and chemicals to a marked degree.

While Molybdenum bearing ores are found widely distributed, the metal up to relatively few years ago was classed as semi-rare or semi-precious as no deposits of real commercial magnitude had been discovered.

A few years ago, the Climax Molybdenum Co. acquired possession of a deposit of Molybdenum sulphide (molybdenite-MoS_2) at Climax, Col., northeast of Leadville. This ore body, by far the largest known, is of such extent and magnitude as to make Molybdenum commercially available on a scale sufficient to meet all requirements of the steel trade.

The flotation mill, at Climax, to treat the crude ore, has at present a capacity of 1,000 tons a day, and at this rate of production, the ore reserves already developed—in this one deposit alone—insures a steady operation for more than thirty years. The entire ore body has not been developed as yet.

The ore is broken, delivered to the mill by aerial tramway, ground and concentrated by oil flotation to from 50 to 70 percent MoS_2. The concentrates are then converted into Ferro-Molybdenum, or Calcium Molybdate, in either of which forms the metal is readily introduced into the steel.

Climax Ferro-Molybdenum is produced in two grades, both containing 50 to 60 per cent metallic Molybdenum, the "Regular" grade is guaranteed to contain a maximum of 2 per cent carbon and the "Special" 5 percent. The former, as the name implies, is generally used. Both are characterized by a low percentage of impurities and great uniformity.

Climax Calcium Molybdate contains about 42 percent metallic Molybdenum, the balance being lime. There is no free carbon or sulphur.

Development During the War

To meet the special demands of war a steel possessing higher physical properties than was heretofore commercially available and which at the same time was capable of being easily machined and heat treated, was required. Molybdenum steels, produced in large quantities, met these demands in many instances.

For example, in the production of the Liberty motor the Molybdenum-Chrome-Nickel crank shafts and connecting rods were used with great success.

Although for many years Molybdenum has been used, particularly abroad, in the manufacture of high speed steels, the properties imparted by fractional percentages of the metal to steel were relatively little understood. This was due, in large part, to the impure alloys of Molybdenum which have been used, and is further accounted for by the fact that metallurgical research received little encouragement because at that time Molybdenum was classed as a decidedly rare element and as such not available in commercial quantities.

During the war and since, many score thousand tons of various types of Molybdenum steels have been produced by the open hearth, electric and crucible practice, the greatest portion having been made in the basic open hearth. The properties which production for war needs showed Molybdenum steel to possess are likely to prove most useful in peace-time industry.

Effect of Molybdenum on Chrome Steel

The addition of Molybdenum to a chrome steel increases the elastic limit to a more marked degree that would be the further addition of chromium, but with the most important difference

that the brittleness is not only not increased but actually decreased, the greater toughness being shown by the higher elongation and reduction of area.

Effect of Molybdenum on Nickel Steel

The addition of Molybdenum to nickle steels containing no chromium results in markedly increasing the elastic limit, and the toughness and ductility for given elastic limits as measured by reduction of area and elongation. This effect is particularly pronounced when the steel is drawn at higher temperatures. The Nickel-Molybdenum steels are characterized by the greater ease with which finished products can be made therefrom, they can be heat treated without detriment to their physical properties in a wider temperature range and are exceptionally homogeneous and free from fibre and "flakes."

General Properties

The makers claim the following general properties:

Heat Treatment.—Molybdenum steels, as a class, are remarkable for the wide temperature range in which they can be treated without detriment to their physical properties.

In spite of the extremely wide range in quenching temperatures, the variation in physical properties is slight. Tests made within a quenching range of as much as 300 deg. Fahr. have also shown practically the same uniformity of results.

Drawing.—In drawing, the temperature to which Molybdenum steels are heated—to develop properties best suited for most general usage—are higher and the variation in physical properties for given temperature difference is smaller than in the case of any other alloy steel.

The wide quenching range and permissibly higher drawing temperatures, with the decreased variations in properties for given temperature changes, mean less costly inspection and fewer rejections.

Warpage.—Molybdenum steels are less liable to warp during course of manufacture, due, in large part, to the depth hardening effect of Molybdenum (which, among other things, permits the quenching of irregular sections with a minimum of warpage) and also as a result of the permissibly higher drawing temperatures which relieve quenching and forging strains. The commercial value of this, particularly for oil hardened parts, as evidenced by the permissible machining limits and the particular elimination of straightening operations during manufacture can hardly be overestimated.

Machinability.—For given elastic limit values, actual shop practice has shown that the molybdenum steels machine easily.

Toughness.—The toughness of the various types of Molybdenum steel is measured by their higher reduction of area for given elastic limits, their ability to resist shock, as measured by the Izod machine, which are greater than in any other alloy yet developed.

Depth Hardening.—It is well known that physical properties developed in heat treated steel are a function of the size of the piece.

Molybdenum steels, while their physical properties are naturally affected by increasing size, are remarkable in that the "effect of section" is very much less pronounced than in the case of other alloy steels.

The commercial advantages of this are evident—not only is the metal in a more uniform condition throughout, permitting deep cuts to be made with minimum decrease in unit strength, but one type of steel is adaptable to more varied "part sizes," thus making for simplification in specification of materials.

Fibre.—Practice has also shown that the inclusion of Molybdenum results in a steel exceptionally free from the so-called "fibrous structure," this being one of the reasons for its extensive use in armor plate during the World War.

Great dynamic toughness and "life" are imparted to steel by the addition of Molybdenum in fractional percentages. Finally, ability to resist shock and alternating stresses conducive to fatigue is characteristic of the various Molybdenum steel types.

Work of Medical Division, Air Service

The War Department authorizes publication of the following from the office, Director of Air Service:

Two medical developments achieved during the war were the establishment of a separate branch of the Surgeon General's Office to investigate and handle the medical problems peculiar to the Air Service and the development of that specialized medical officer known as the Flight Surgeon.

The question naturally arises as to why there should be a special Air Medical Service, or why there should be a Flight Surgeon distinct from any other medical officer. This is answered by the following statements:

The medical problems of aviation are new and entirely different from those of any other branch of the service.

The medical care of the flier can be carried out only by an especially trained surgeon.

The advantages of a special Air Medical Service were first demonstrated by Great Britain. During the first year of the war her air casualties were said to have been caused as follows: Due to Germans, 2 per cent; due to defective planes, 8 per cent, and due to physical defects of pilots, 90 per cent. Great Britain then established an independent Air Medical Service and specialized on the care of the flier. The next year the 90 per cent (physical defects of pilots) was reduced to 20 per cent, and the following year to 12 per cent.

When the United States entered the war it was decided to follow the advice of our Allies and select specialists in the several branches of medical science, assigning them to duty with the Air Service. It was discovered that we knew little or nothing about the medical problems of aviation and in order properly to investigate these problems the Medical Research Laboratory of the Air Service was established at Mineola, New York. It was subdivided into seven professional departments and each department studied the problems of aviation in its own particular field. These departments were physiology, heart and blood vessels, eye, ear, psychology, psychiatry and physics.

The most important phase of the work to attract attention was the effect of low oxygen percentage on the circulation, respiration, mental reaction and the eye of the flier. The low pressure tank was installed which simulated the atmospheric conditions extending from sea level up to approximately 36,000 ft. Later a rebreathing machine was developed which was safer and simpler to operate. Briefly, the man being tested breathed over and over again the same air with the impurities removed. The oxygen, of course, was constantly diminished and the result was similar to that in the tank, for it was early found that the important factor in altitude was the decrease in oxygen percentage and that the decrease in atmospheric pressure and temperature were secondary considerations.

The specialized work of the Medical Division, Air Service, comprises three divisions: The selection of the flier, the classification of the flier, and the maintenance of the flier. First of all, it was soon discovered that the standard physical examination for entrance to the Army was not sufficient for the Air Service fliers. One of the most important things for a flier to have is good eyes, and by good eyes was meant not only eyes that can see well straight ahead, but eyes that, while looking at one object clearly, are aware of surrounding objects. The eye muscles must be well balanced, so that there is no tendency to see double, which tendency becomes quite manifest under fatigue and the strain of high altitudes. The flier must be able to judge accurately the relative position of objects. This is called stereoscopic vision and it takes excellent stereoscopic vision to make a landing with an airplane. Special apparatus for making many of these tests was devised at Mineola and used in the service.

In the ear, nose and throat examination, a normal nose and throat are insisted upon. Diseased or enlarged tonsils, or a badly deflected nasal septum which interferes with free breathing must be corrected. The condition of the ear drums must be healthy. Any perforation of the drums, or a discharge from the middle ear is a cause for rejection. Hearing must be absolutely normal. It is also essential that the sense of equilibrium, which is a function of the internal ear, be normal. This is tested by the turning chair, which is now well known.

The general physical examination is similar to that adopted for recruits for the Army except that the standards are more rigidly adhered to. In addition to the physical examination, a personality study is made in each case. The objects of this examination are to detect nervous and mental diseases which may render the candidate temporarily or permanently unfit for the service, to form a definite idea as to what extent the aviator will stand the strain on arriving at the front, and to determine the existence of any latent tendencies which, under the stress of actual warfare, would become so accentuated as to make him inefficient and increase his susceptibility to nervous and mental collapse. The vital importance of such a determination of personality trend and potentiality is seen in the fact that apart from the disability arising from epidemics, probably 70 per cent of the cases of lowered efficiency among aviators is due to a break, either partial or complete, in the nervous system. This condition is termed staleness. The early recognition of the symptoms of such staleness counts primarily as a means of preventing crashes with their attendant injuries and the maintenance of a high degree of efficiency in the Air Service.

After selecting the candidates for flying the surgeons proceed to classify them. This is based on the information which has been discovered at the Medical Research Laboratory by means of the rebreathing machine. First of all the aviator is given a general physical examination, including an examination of his eyes. He is also given a personality rating. The candidate is then given the rebreathing examination, including tests as to the reaction of his heart, circulation, respiration, attention and motor coordination.

The men are then graded into four classes, as determined by the needs of the service. Class D men are grounded, they being those found totally unfit to fly. Class C are allowed to fly up to 10,000 ft. Class B are allowed to fly up to 15,000 ft., and Class A may fly at any altitude.

Combat work is done at very high altitudes, day bombing at moderate altitudes, and night bombing and reconnaissance at low altitudes, so that these three classifications meet the needs of the service. Of the A, B and C classes, about 61 per cent are rated A, 21 per cent B, and 14 per cent C. So by these methods, flight surgeons are able to determine, before a flyer ever leaves the ground, the altitude to which he may safely fly.

The Pioneer Turn Indicator

By Charles H. Colvin

Flying in fog or clouds, or at night, the greatest difficulty is experienced in holding an airplane on a straight course. The compass is of little help as its successful operation depends largely upon a straight course being maintained, and once a turn is started, throwing the compass off meridian, it offers no assistance whatever in regaining a desired heading.

It is apparent that what is required is an instrument which will show when the plane is turning. By steering so as to prevent this instrument from indicating, a straight course can be maintained, the direction of which is given by the compass.

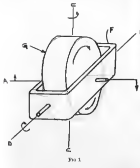


Fig 1

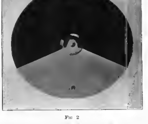


Fig 2

Should a turn be started its direction will be indicated and the plane can be quickly straightened out.

Numerous attempts, more or less successful, have been made to construct a turn indicator utilizing the difference in the speed between the two wing tips, or the centrifugal force on the plane when turning. The forces available for such indications are very small, and any instrument using them is too delicate for practical use.

The gyroscope offers a much simpler and more practical solution of the problem, as the forces available are relatively large. In the Pioneer Turn Indicator the force necessary for operating the indicator is obtained from the reaction of a small gyroscope to the turning movement of the plane. The principles of the instrument are best illustrated by reference to the sketch, Fig 1.

Fig. 3

Here the gyroscopic wheel G is shown mounted in a frame F on the axis AA, which is athwartship and normally horizontal. The frame is mounted in the case of the instrument on the fore and-aft axis BB With the wheel running in the direction shown by the arrows, suppose the airplane carrying the instrument to make a left turn, as indicated by the arrow about the axis CC This movement will cause the gyroscopic wheel to react or "precess," about the axis BB as indicated by the arrow In other words the axis AA of the gyro is displaced as shown by the arrows on the line AA In the instrument the frame carries a shutter (Fig 2) having a white sector which in this case would be brought up into view behind the left hand opening on the dial of the instrument (Fig 3) indicating a left turn.

In the actual construction of the instrument many problems had to be worked out. Some experimenting was necessary to determine the best size and weight of the gyro and no little difficulty was experienced with ball bearings. The sensitive element as finally adopted is shown in Fig 4

The gyro wheel is carried on small Fafnir ball bearings, and normally runs at about 7,000 r.p.m The bearings are oiled from a reservoir within the gyro wheel Oil is added through an oil hole in the shaft by removing the oiling screw on the right hand side of the case of the instrument (Fig 3) The gyro frame is of cast aluminum alloy and is carried on Fafnir ball bearings fore-and aft The gyro has grooves or "buckets" cut in its periphery, and is driven by the impingement of a jet of air, which is brought in through the rear bearing.

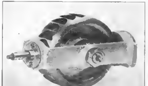


Fig. 4

The sensitive element is held normally in the central position by a spring, against which the gyroscopic force acts in indicating a turn. The amount of indication is closely proportional to the speed of turning A damper on the precession axis prevents excessive oscillation of the indicator, which is practically dead-beat.

Power for operating is obtained from a compound venturi tube (Fig 5) placed in the air stream. This partially evacuates the case of the instrument, and atmospheric air rushes in through the jet, driving the wheel Some trouble was experienced due to moisture being drawn into the case, but this has been remedied by using a flexible metal intake tube of sufficient length so that air can be drawn from the engine section or any other suitable location.

As the turn indicator is used with the compass, and should be placed close to it, it is important that the instrument be non-magnetic. This has been accomplished in the Pioneer instrument by using bronze and aluminum throughout the construction, the only steel being in the ball bearings.

A sensitivity controller forms a part of the instrument, as it has been found that different ships, pilots, and kinds of weather demand different degrees of sensitiveness of indication. The combination pointer and valve handle on the face of the instrument is used to throttle on the vacuum line, and so control the speed of the gyro with the resulting variation of the sensitiveness. The wheel may be shut off entirely when it is not needed.

Fig. 5

These instruments have been made so sensitive that a turn which would require an hour and a half for a complete circle is clearly indicated. For ordinary use on a plane, however, it has been found best to set the instrument for a minimum indication on a turn at the rate of one circle in about twenty-two minutes.

Once installed the instrument requires no attention beyond an occasional oiling, and its use permits the safe navigation of planes in weather which would otherwise prohibit flying altogether. The Pioneer turn indicator is used by the Post Office Department on their mail planes, and is manufactured by the Pioneer Instrument Co of New York City

Book Review

Aeronautics. By Prof Edwin Bidwell Wilson. (John Wiley and Sons, Inc. 265 pp.)

For several years, Professor Wilson has been giving, at the Massachusetts Institute of Technology, courses of lectures on those portions of dynamics, both rigid and fluid, which are of fundamental interest in aeronautics. While the fundamental principles present considerable mathematical difficulties, they are essential to the aeronautical engineer or research student in aerodynamics

Former students of Prof. Wilson will undoubtedly regret that they did not have this book available in taking his lectures The author has treated in simple form all the preliminary mathematics, and he has made the subject comparatively easy Beginning with the skeleton airplane, he passes on to a simplified study of harmonic motion, motion in two dimensions, to the elements of stability.

It cannot be said that previous writers on the subject, such as Bryan, Bairstow and Hunsaker, have made as readily understandable a presentation. In dealing with fluid dynamics, as applied to aeronautics, the same object has been kept in view. Professor Wilson has given us a very valuable work

The Junkers Armored Two-Seater Biplane.-Type J. 1*

As the data upon which this report is based were collected from the debris of two examples, both of which were entirely dismantled and greatly damaged, there are points upon which a certain amount of uncertainty must exist. The utmost care has been taken, however, in the reconstruction of the machine, and doubtful points are specified.

General

The Junkers is radically different from the usual type of airplane, whether considered from the point of view of design or of actual construction. (Fig 1.)

It is evidently a serious attempt to reduce to a minimum the dangers due to enemy action while in flight, and to lengthen the life and endurance of the machine in spite of exposure to bad weather and to rough handling To this end the machine is armored, and all vulnerable units, so far as possible, are gathered within the armored portion. Inflammable materials, and those which suffer rapid deterioration when exposed to rough weather, are almost eliminated Tension bracing by means of wire cable is entirely absent, rigidity in planes, fuselage and undercarriage being obtained in all cases by metal tubes. Even the aileron control is without wiring, and careful search has failed to reveal any constructional wiring, save that of the elevator and rudder controls

No information is to hand regarding performance, but it is known that the machine requires an exceptionally long run before getting off.

General Particulars and Dimensions

Weights—Figures painted on fuselage gave.—

	lb.
Weight, empty	3,724
Useful weight	845
Total weight	4,569

Engine—230 hp Benz.
Crew—Two, pilot and observer gunner.
Gasoline Capacity—26 gal.
Oil Capacity—10 gal.
Weight Per Horsepower—19.9 lb
Loading Per Square Foot—8.56 lb

Dimensions

	sq. ft.
Area of upper center section	134.7
Area of each upper plane (with aileron)	125.8
Area of complete upper wing (with ailerons)	386.3
Area of each aileron	62.0
Area of balance of aileron	2.4
Area of lower center section	48.0
Area of each lower plane	49.6
Area of complete lower wing	147.2
Area of total wing surface	533.6
Horizontal area of fuselage	62.1
Vertical area of fuselage	76.6
Area of fin	12.0
Area of rudder	15.4
Area of balance of rudder	1.6
Area of fixed tail planes (both sides)	49.0
Area of elevators (both)	33.6

Wings

General Design—The upper plane has a large center section (rectangular except for the cut-away portion over the pilot's head), which is strongly braced to the fuselage by means of a system of steel tube struts The leading edges of the upper planes are set back at an angle of approximately 5 deg. from the line of the center section leading edge, but the trailing edges are at right angles to the line of flight for by far the greater part of their length.

The lower planes follow more or less the same plan, but the lower center section is very much smaller than the upper, and is built up in one unit with the undercarriage. To this unit the fuselage is firmly fixed by short steel tube struts, and an aluminum fairing is built around that part of the fuselage which is adjacent to the center section's upper surface. There are apparently two attachments which directly couple the fuselage to the center section unit These take the form of lugs fitted to the two bottom edges of the octagonal body, midway between the forward pair of strut attachments. The lugs are bolted to corresponding lugs welded on to steel sleeves, which are in turn riveted to two upper duralumin spars of the lower center section. The aluminum cowl which bridges the gap between body and lower center section is simply a fairing To each side of the lower center section is fixed a side plane, which tapers in plan view from both front and rear toward the tips.

The damaged condition of the machines under examination has prevented absolute certainty on the question of dihedral, but there are excellent grounds for believing that the front view of the machine approximates very closely to the true disposition of the planes. It will be seen on reference to this view that the upper surface of the upper wings is horizontal as in the D-7 Fokker, and on this point there is hardly any doubt. There is undoubtedly a dihedral on the lower planes, but the exact angle of dihedral is a matter of estimation. The angle given in the drawings, viz., 3 deg., is probably very near the truth. It will also be noticed from the scale drawings that the angle of incidence has been estimated at 3 deg. for both upper and lower planes

* Issued by Directorate of Research, British Air Ministry

Fig. 1 A Batch of Junkers Armored Two-Seaters at a German Aerodrome

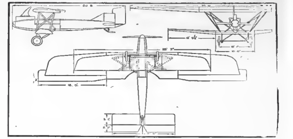


FIG 2 OUTLINE DRAWINGS OF THE JUNKERS J. 1 ARMORED BIPLANE

The planes are based on the Fokker principle, i.e., they are made sufficiently strong to obviate the necessity for external wire bracing.

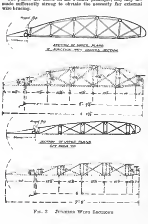


FIG. 3 JUNKERS WING SECTIONS

The port and starboard planes, both upper and lower, depend entirely for their support upon the spar joints.

Wing Section

Sections drawn to scale are shown in Fig 3 There is a good deal of similarity between the Junkers and the Fokker aerofoils, but it must be remembered that the Junker wings are set at an appreciable angle of incidence, whereas the Fokker planes are without incidence.

Wing Construction

It is in this particular that the greatest departure from established practice is found. The planes are constructed entirely of metal, even to the covering A description of the constructional features of one of the upper planes will explain the system upon which the wings are built.

Each upper plane contains ten spars of duralumin tube, without counting the aileron tube. Fig 3 gives a section drawn to scale, showing the disposition of these spars, and the lower half of the diagram gives all dimensions, including the diameters and gages of the tubes. The tubular spars are braced to each other by means of smaller tubes, also of duralumin. The exact system employed is shown in Fig 4. It will be noticed that steel sleeves are riveted at intervals along the spars, and that the bracing tubes are flattened out at the ends and riveted to small, flat plates welded on to the steel collars.

The constructional methods already described as being found in the upper planes are followed throughout both wings and center sections, except that toward the tips the place of the bracing tubes is taken by strips of duralumin longitudinally grooved to resist bending strains. Fig 4 (7) shows this, and also makes it clear that the steel collars to which the bracing tubes are riveted are not found where strips are employed. Some of the wing spars are spliced, a tube of larger diameter being joined to one of smaller diameter by being pressed into a square section and riveted in place. Fig. 5 shows how two portions of equal-sized tube are joined by means of a steel collar.

The way in which the wings are joined to the center sections is simple and effective. Reference to Fig 4 (8) shows that each of the spars is fitted with a steel sleeve which fits inside the duralumin tube and is riveted in place. One sleeve carries a threaded collar, beveled, as shown The opposite spar has a similar internal liner of steel, riveted in place, and a loose internally threaded steel collar. The end of the liner is beveled to take the bevel of the opposite spar. Thus, when the bevels are fitted together and the collar screwed on to the male thread, a firm and rigid joint is made. When it is remembered that all the numerous tubes are joined in this manner, it is evident that the junction of wing to center section is of great strength. Indeed, the designer has trusted solely to these joints to take all lift, drag and landing strains, for there are no other attachments of any sort between wings and center sections.

The sheet duralumin covering is .015 in. thick (roughly 28 S.W G.). It is corrugated so that a section cut parallel to the trailing edge is waved and the pitch of the wave is 1¾ in., the depth being ⅓ in. The sheets are riveted together by aluminum rivets spaced at intervals of 1.8 in. The sheet weighs 3.65 oz per sq ft of area, not allowing for lap in riveting (It may be remarked that an approximate average weight for the usual German wing fabric, including dope, etc., is 1 oz. per sq ft.)

Analysis of the material shows:

Copper	4.46	Zinc	Nil
Tin	Nil	Manganese	0.28
Lead	Trace	Magnesium	0.30
Iron	0.80	Silicon	0.39

This analysis shows that the material is "Duralumin."

Physical Tests

Test pieces cut from the sheet in two perpendicular directions gave:

	A.	B.	
Yield	18.2	18.1	tons per sq in
Ultimate	18.8	19.4	tons per sq in
Elongation	3.3	6.3	per cent.
Reverse bends	3	3	per cent

These values correspond to a strength of 850 lb. per in.

(The above figures are much below the requirements of Air Board Specification for Duralumin sheet.)

Micro-Examination

The micro-structure shows that the sheet has apparently not been heat treated after rolling, the section showing the elongated crystalline structure characteristic of cold rolled material.

Ailerons

It is evident from the scale drawings and photographs that the upper plane only is furnished with ailerons, that the ailerons are of the balanced type, and that each one reaches from the center section to the wing tip

The construction is simple. A duralumin tube passes from end to end, along the front lower edge, and to this is riveted the duralumin sheet which forms the lower surface of the aileron The two sheets are riveted together at the rear

A hinged strip, about 4 in wide and capable of moving upward only, is fixed near the rear edge of the upper plane, thus bridging the gap between aileron and wing

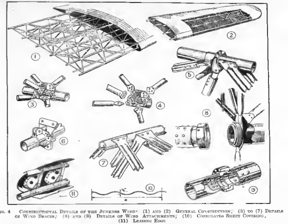


FIG. 4 CONSTRUCTIONAL DETAILS OF THE JUNKERS WING: (1) AND (2) GENERAL CONSTRUCTION; (3) TO (7) DETAILS OF WING BRACES; (8) AND (9) DETAILS OF WING ATTACHMENTS; (10) CORRUGATED SHEET COVERING, (11) LEADING EDGE

Struts

The arrangement of struts is one of the most interesting features of the Junker biplane. Examination of Figs 1 and 2 will reveal the fact that there are three groups of struts.

1. Struts connecting upper plane to lower plane. There are two pairs of these one pair on each side of the body.
2. Struts connecting the upper extremities of the outer struts to the lower edge of the fuselage side. It will be noticed that these struts cross from front to rear, and that interference

between the two is prevented by arranging that their upper extremities fall on different chords (see front view, general arrangement drawings)

3 Struts connecting the lower edge of the fuselage side to those points in the lower plane to which the undercarriage struts are fixed.

All these struts are of steel tube covered with aluminum fairing Steel formers are welded to the tube at intervals, and to these the fairing is riveted. The two edges of the fairing

Fig 5 Longeron Splice

are turned in and joined together, at the narrow rear edge, by means of split pins. The longer tubes at least, and probably all, are of 4 cm diameter and 15 gage. They are joined to the spars by means of riveted steel collars carrying welded-on lugs.

At the fuselage, the struts finish in fork-ends, and are bolted to lugs welded to small steel plates riveted to the armor-plate.

Fuselage

The body of the Junkers is constructed in two distinct parts —a front armored portion, and a rear portion built up of duralumin tubes.

The armored part is built of 5 mm steel plate The Junkers is not an ordinary two-seater machine to which armor has been subsequently added, but the armor plate comprises the fuselage, as would be expected. The various photographs show clearly the shape of the body, also the number and size of the plates which are riveted together The bracing strips are made of duralumin.

The armored unit houses the engine, pilot and gunner, and the petrol tank The vertical cowl surrounding the engine cylinders is of armor plate, and is not a mere fairing The spinner which covers the propeller boss is made of aluminum. The armoring is very thorough, so that the chances of a bullet finding a vulnerable spot are small

The rear portion of the body is built of duralumin tube throughout, and is covered with laced-on fabric. There are four longerons, so arranged that the fuselage ends in a vertical knife-edge about 10 in long Cross tubes are arranged horizontally and vertically at intervals. The diagonal bracing is not of wire, as is the case in the D-7 Fokker and the A E G (which, it will be remembered, also have fuselages of metallic tubes) Diagonal tubes perform this function in the Junker

The junction of the duralumin tubes is effected by means of steel sleeves which embrace the longerons tightly and are pinned to them The shape of one of these clips is shown in Fig 6 It will be noticed that the cross and diagonal tubes are flattened at their extremities and riveted to approximate shelves welded on to the clip Three ply formers are fixed to the upper and lower cross tubes, and (in the case of the deeper lower formers, at any rate) are joined by light wood stringers which pass from the end of the armored portion to the front end of the tail skid

The rear portion of the body is a structure of great strength. The vertical tubes in the last two bays before the stern-post are replaced by strong bulkheads of duralumin sheet The construction is made clear in the drawing of the fuselage, which shows that the upper and lower longerons on each side are joined by duralumin sheet of channel section, which is wider at the middle than at either end A rectangular sheet of corrugated duralumin is riveted on either side of the vertical channel girder, and inside the box thus formed are two stout duralumin tubes, the extremities of which carry beveled steel collars similar to those on the ends of the wing spars. The space between the duralumin tubes and the front corrugated sheet is bridged by two duralumin channels, riveted at the front to the corrugated sheet, and at the rear to the tubes.

This construction is repeated in the next bay, and at the rear the pair of horizontal tubes are firmly attached to the sternpost All six horizontal tubes are of equal length, and the exposed portions are covered by a flat duralumin sheet, as indicated.

It will be noticed that the longerons are not of the same diameter throughout, but are spliced toward the rear of the fourth bay (counting from the armored portion). The character of the splice is precisely similar to that employed in the wing spars described above and illustrated in Fig. 5

About 5 ft. from the sternpost the fuselage drawings indicate a kind of horizontal grid which is fixed to the lower longerons. This comprises a steel tube structure which takes no part in strengthening the fuselage, but is intended solely to provide handles for lifting the rear part of the body of the machine.

The two short tubes, shown in the side view, above and at each side of the handles are duralumin guides for the control cables.

The junction of the two parts of the fuselage is very simple. From the outside the longerons are seen to be butted up to the rear armor plate of the observer's cockpit, but no means of attachment is visible. Investigation from the interior of the cockpit shows that a substantial castellated steel nut is screwed over a steel bolt of about ½ in. diameter, and secured in place by the usual split pin. It was not possible to ascertain the exact manner of fixing the stud of the bolt into the end of the tubular longeron Only the usual riveted steel collar to which the bracing tubes are riveted appears on the outside.

Undercarriage

This is built to form one unit with the lower center section. There are two vees which are of normal design, except that a supplementary tube is welded to the upper extremity of the forward limb and to a point just below the middle of the rear tube. The vees are parallel and vertical. The shock absorbing device does not present any unusual feature. Twin coil spring is employed and a double loop of cable limits the upward travel of the axle, while a radius rod controls the movements of the axle It will be noticed also from Fig 1 that each vee is stayed by means of a steel tube, which connects the lower part of the front limb to the middle of the lower center section, and that wire bracing is entirely absent.

The axle is a steel tube nearly 9 ft. long In common with all other exposed tubes in the machine, it is faired with sheet aluminum, which is riveted to transverse webs (also of alumi-

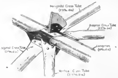


Fig 6 Fuselage Construction Detail

num), which are in turn riveted to the axle tube. The fairing is, therefore, of the type that rises with the axle when the machine lands There are no compression tubes fitted parallel to the axle, since the extra pair of tubes already mentioned render this unnecessary Incidentally, they also eliminate wire-bracing

Tail

The rear portion of the fuselage has already been described and mention has been made of six short horizontal tubes which finish in steel screw-collars. The two halves of the fixed tail

Fig 7 View of the Junkers Cabin Plane after its Crash at Roosevelt Field

Wide World Photos

plane are held in position solely by these joints. The section of the tail plane is of approximately the same shape as that of the wing. It contains seven tubular spars—one single tube in front and three pairs at intervals behind, and the greatest depth is approximately 7¼ in. The covering is exactly similar to that of the wings, as also is the internal construction. The front spar is not fixed in any way to the fuselage, and the front foot or so of the tail plane simply abuts against the fabric.

The construction of the divided elevator is very simple. At the front is a duralumin tube hinged to the rear edge of the tail plane. There are six such hinges altogether—three to each half of the elevator. The corrugated duralumin covering is riveted to the spar and is also held together at the rear edge by rivets.

The tail skid is a substantial piece of ash bound with fabric, pivoted about its middle point and fitted at the lower extremity with a welded steel shoe. The shock absorber consists of the usual steel coil spring. The four tubes which carry the tail skid are in the form of a pyramid, and are composed of steel. The fairing is of sheet steel welded on, which adds considerably to the strength of the structure.

Engine and Engine Mounting

The engine installed is a 230 hp Benz, and it is remarkable that in such an all-metal type of machine the engine bearers are of ash. The bearers have steel supports and are braced to the side by means of duralumin tubes of 20 mm diameter. The petrol tank is an elaborate structure of sheet brass, built up into the form of an armchair and is capable of carrying 26 gal.

Dimensions.—The following are the principal dimensions of the Junkers J-1 armored biplane:

Span, upper plane	53 ft
Span, lower plane	35 ft 7 in
Overall length	29 ft 8 in
Overall height	11 ft 4 in
Span of ailerons	16 ft
Span of horizontal stabilizer	17 ft
Chord of upper center section	6 ft 2 in
Chord of lower center section	4 ft 10 in
Gap at wing roots	8 ft 4 in
Chord of horizontal stabilizer	3 ft 1 in
Chord of elevator	3 ft 1 in
Chord of aileron	1 ft 8 in
Track of undercarriage	8 ft 1 in

The angle of incidence of both planes is estimated at 3 deg, the sweepback at 5 deg. and the dihedral of the lower plane at 3 deg There is no dihedral to the upper plane.*

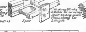
*The original report of the British Air Ministry calls the machine under review the Junker. Information which has reached the editor from abroad shows conclusively that the designer of this plane spells his name Junkers, and not Junker hence this correction has been applied in the report. It will be of interest to know that Professor Junkers has always been an exponent of monoplane design and that he designed the armored biplane on orders from the German War Ministry against his own beliefs. The truth of this assertion is borne out by the fact that his first post war product was the Junkers cabin monoplane a specimen of which has recently been imported into the United States, and which crashed on its trials at Roosevelt Field. Fig 7 illustrates this machine as it looked after the crash. It is notable that although the airplane hit the ground with one wing the construction of the fuselage proved strong enough to withstand the resultant crushing so that the pilot came out of the crash without a scratch —Editor.

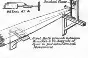
Siemens-Schuckert Giant Plane, Fitted with Six Basse & Selve 300 HP Engines. The Overall Span Is 118 Ft.

The Vibration of Spars in Aircraft

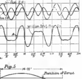
The following investigation was commenced with the view of determining the cause of the vibrations which were found to exist in the lower plane of an airplane at high engine speeds. The position of the interplane struts was found to play so important a part, however, that this part of the subject was investigated in considerable detail.

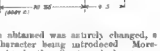
Fig. 1 shows the disposition of the wing spars and strut of the machine in question. The strut made contact with the rear spar of the lower plane at a point one-third of the spar's length from the free end. This fact suggested that the trouble was the result of the natural vibration of the spar, the strut being placed at the node of the harmonic of the third order.





The machine was supported with its flying axis vertical, and a needle inserted in the free end of the spar. The spar was then set in vibration while a smoked glass plate was moved in a vertical plane across the needle point, at a known speed by means of a clockwork device. In this way the frequency of the spar's vibration was determined. The experiment showed beyond doubt that the natural vibration of the spar synchronised with the revolutions of the engine at the speed at which the trouble was experienced. Except for the diminishing amplitude the curve recorded on the smoked glass was an almost perfect sine curve. The strut was moved outwards a few inches and the experiment repeated. The character of the curve obtained was entirely changed, a very marked harmonical character being introduced. Moreover, for a given initial amplitude, the vibration died out very much more rapidly than was the case when the sine curve was recorded.

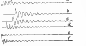


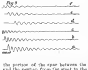


In order to investigate in detail the influence of the strut position on the vibrations of a spar, a spar was secured to the wall by the means shown in Figs. 2 and 3. The end of the spar which was attached to the fuselage, was rigidly held between blocks secured by long bolts. Fig. 2 shows how the strut position was reproduced. By slackening the nuts of the bolts these blocks could be placed in any required position. At the free end of the spar a needle was fixed (for detail see A in Fig. 3), which pressed lightly against a smoked glass plate which could be raised between grooves by means of clockwork not shown in the figure. The spar rode lightly on steel balls, carried between two brass plates, at two points in its length. These prevented motion in a vertical plane and corresponded to the compression ribs in a built-up wing.

The experimental spar was 14.75 ft. long, and for the strut to be at the node of the harmonic of the third order, it must be placed $\frac{14.75}{3} = 4.92$ ft. from the free end. In the machine mentioned above the amount which it was possible to move the strut was limited not only by considerations of stress, but also by the fact that too great a movement would introduce the same trouble into the upper plane. A movement which would place the strut midway between the nodes of the upper and lower planes would give a corresponding movement of 5 in. on the experimental spar, that is, to a position 4.5 ft. from the free end.

The clamp was placed in this position and a record obtained on the smoked glass plate (which was subsequently immersed in weak varnish and reproduced photographically). The record is shown at a in Fig. 7. The clamp was now moved to the nodal position, viz., 4.92 ft. from the free end, and another record obtained which is shown at b in Fig. 7.





Now the latter graph is a fairly pure sine curve (with a diminishing amplitude of course), whereas the former curve a obviously contains the harmonic of the fifth order at least.

Analysis gives the equation:

$$y = \sin 3\theta + \tfrac{1}{2} \sin 5\theta$$

The graph of this equation has been plotted, and is shown in Fig. 4. For the purpose of comparing it with the photographic record the graph should be regarded as commencing at A. The two terms of the equation seem to indicate that the vibration is the resultant of the natural vibrations of the portion of the spar between the fixed end and the strut, and the portion from the strut to the free end. The period of these vibrations will obviously be different, and the form of vibration to be expected is that shown in Fig. 5. This, however, does not support the equation obtained by analysis. Fig. 6 shows an alternative form of vibration.

In this case the wave length (λ_1) of the longer portion is 10.25 ft. and that (λ_2) of the extension is $\frac{4}{3} \times 4.5 = 6$ ft. The ratio $\frac{\lambda_1}{\lambda_2} = \frac{10.25}{6.0} = 1.71$, whereas the ratio indicated by the equation is $5/3 = 1.67$. The agreement between the two is as close as can be expected, when it is remembered that the experimental spar is not of uniform section.

Now if the strut is so placed on a spar as to avoid the node of any low harmonic, the spar is compelled to vibrate (if it vibrate at all) in the manner described above. This has two advantages:—

1. The natural vibrations of the spar are less likely to synchronise with the revolutions of the engine.
2. The vibrations, when set up, will die out much more quickly than they will if the whole spar is vibrating with the same period.

In order to have some indication of the effects of moving the strut more and more from the nodal position of the harmonic of the third order, a number of records were taken, and are shown in Fig. 8. a was taken with the strut at the node (i.e., 4.92 ft. from the free end). The strut was then moved outwards with intervals of 4 in., hence the records b, c, d, e, and f, were obtained with the strut 4 in., 8 in., 12 in., 16 in. and 20 in. outside the node respectively. It will be observed that higher and higher harmonics are introduced into these graphs as the strut is moved outwards. It has not been thought worth while to apply harmonic analysis to these graphs.

Fig. 9 shows a similar set of traces, of which a was taken with the strut at the node, and the remainder with the strut moved successively 4 in. inwards (i.e., towards the fixed end). It will be observed that these graphs are practically pure sine curves, and it seems likely that the bulk of the vibration is due to the movement of the extension only, the portion between the fixed end and the strut becoming more and more nearly rigid. If this is so the wave-lengths of the graphs should vary directly as the lengths of the extensions, since the wave-length of the fundamental vibration of the extension will be four times its length. The following table gives the measured values, and fully justifies this hypothesis.

—	Wave-length of Graph.	Wave-length of Extension Vibration	Wave-length Reduced to Common Unit: Graph.	Extension.
	in.	ft.		
a	0.307	18.38	1.00	1.00
b	0.315	21.0	1.03	1.07
c	0.337	22.32	1.10	1.13
d	0.370	23.68	1.20	1.20
e	0.392	25.0	1.28	1.27
f	0.408	26.32	1.33	1.34

Of course, where a machine has only one pair of interplane struts, questions of stress give a very small range of choice of position for the strut, but these experiments seem to point to the wisdom of avoiding any position more remote from the free end than 30.5 per cent. of the whole length.—*Engineering*

Comparative Merits of Dixie Magnetos and Delco Battery Ignition System When Used on a Liberty "12" Aero Engine

Object of Test

To determine the comparative ability of Dixie magnetos and the Delco battery system to keep spark plugs firing in the Liberty engine under adverse conditions and to determine the difference in resultant power output with the two systems, if any exists.

Conclusions

The tests show no appreciable difference in power or freedom from fouling of spark plugs.

Description

Delco Battery System—The ignition system used for this test was the standard ignition system used on the Liberty 12-cylinder engine mounted in the usual manner. It consists of a battery, a generator, two coils, and two distributor heads, each distributor head firing one set of 12 spark plugs. It is manufactured by the Dayton Engineering Laboratories Co., of Dayton, Ohio.

Dixie Magneto System—Two model 1,200, 12-cylinder Dixie magnetos were used for this test. They were manufactured by the Splitdorf Electrical Co., Newark, N. J. The two magnetos, each of which fired a set of 12 spark plugs, were mounted transversely at the rear of the engine on a sturdy aluminum bracket and were driven from the splined end of the crankshaft through two helical gears. The method of mounting is almost identical with that used for driving the Dixie magnetos on the 300-horsepower Hispano-Suiza 8-cylinder engines.

Method of Test

The engine was connected to an electric cradle dynamometer in the customary manner. Tests were first conducted to determine the difference in fouling of spark plugs when used with magneto and battery ignition. To determine this the engine was run with each ignition system in turn for one-half hour at idling speed and then one hour at normal speed under full throttle operation, allowing one gallon of lubricating oil to flow into the intake system during each run. For the idling tests the Delco was run with one switch off and the ignition fully retarded, while the Dixie ignition was operated with fixed spark, 30° advance. For the full throttle runs both ignition systems were set to 30° advance. The oil was supplied from a calibrated container, the amount of flow from it being regulated by means of a valve. A run was first made feeding the oil into the air horn of the carburetor, but it was found that the oil was not sucked in to the cylinders by this method. The center petcock of each of the four intake manifolds was then employed and four outlets from the container connected to these petcocks by means of rubber tubes. The following runs were then made under the conditions named above:

Run No. 1—One-half hour with Delco ignition at idling speed, feeding 1 gallon of oil from the calibrated tank.

Run No. 2—A repetition of the first run, but using the Dixie magneto ignition.

Run No. 3—One hour at full throttle, using Delco ignition and feeding one gallon of oil into the manifold as in the previous runs.

Run No. 4—One hour at full throttle similar to the third run, but using Dixie magneto ignition.

It was believed that better results could be obtained by distributing the oil to each individual cylinder of the engine. An individual tube was therefore led to each one of the 12 manifold petcocks, each of which is located over the intake valve of one cylinder, and the oil was fed through them into the cylinders. The following runs were than made:

Run No. 5—One-half hour at idling speed, using Dixie magneto ignition and feeding in one gallon of oil.

As run No. 5 gave no different results from the runs where oil was introduced into four petcocks only, no further runs for plug fouling were considered necessary.

When these runs were completed an attempt was made to determine the difference in power when using the two systems of ignition, and the following additional runs were performed, readings being taken at every 200 revolutions per minute from 1,300 to 1,900 revolutions per minute, inclusive.

Run No. 6.—Full power curve with spark set at best position at 1,700 revolutions per minute and not changed during run, Delco ignition.

Run No. 7.—Same as No. 6, but using Dixie magneto ignition.

Run No. 8.—Spark set for best power at each speed, using Delco ignition.

Run No. 9.—Same as No. 8, using Dixie ignition.

Except as above noted, the power curves were made according to the standard laboratory method (see Power Plants Report No. 69), the carbureter controls being set for best performance at each speed.

Results of Test

The results of the test are compared below. It will be noted that plug fouling during runs when oil was admitted was about the same for both systems. The power results also appear to be the same within experimental error.

Dixie-Delco Comparison Test

Test results, plug fouling runs

ONE-HALF HOUR (MAGNETO IGNITION), FIRST RUN

Revolutions per minute	Brake horse-power	Temperature: Water out (°F)	Temperature: Oil out (°F)	Oil pressure (pounds per square inch)
340	66	122	98	13

At the end of the run only four cylinders were firing perfectly. Seven more were firing on one plug and one was not firing at all.

HOUR (BATTERY IGNITION), SECOND RUN

Revolutions per minute	Brake horse-power	Temperature: Water out (°F)	Temperature: Oil out (°F)	Oil pressure (pounds per square inch)
330	55	120	96	10

At the end of the run 11 of the cylinders were firing, 7 of them perfectly, 4 were firing on one plug and 1 cylinder was not firing at all.

ONE-HOUR (MAGNETO IGNITION), THIRD RUN

Revolutions per minute	Brake horse-power	Temperature: Water out (°F)	Temperature: Oil out (°F)	Oil pressure (pounds per square inch)	Fuel consumption (pounds per horse-power-hour)
1,725	422	165	126	49	0 475

All plugs firing

ONE-HOUR (BATTERY IGNITION), FOURTH RUN

Revolutions per minute	Brake horse-power	Temperature: Water out (°F)	Temperature: Oil out (°F)	Oil pressure (pounds per square inch)	Fuel consumption (pounds per horse-power-hour)
1,730	413	170	121	52	0 475

All plugs firing

FULL POWER COMPARISON TABLE

(Corrected brake horsepower)

Revolutions per minute	Fixed spark: Magneto	Fixed spark: Battery	Adjusted spark: Magneto	Adjusted spark: Battery
1,300	338	335	315	340
1,500	394	390	368	392
1,700	439	446	435	438
1 900	459	418	440	445

Observations During Test

During the runs when oil was admitted, the engine ran well except for the spark plug fouling already noted No trouble was experienced in the full power runs with either system.

Analysis of Results

When the engine was run at idling speeds, the plugs fouled equally, no matter what system of ignition was used. The difference in power output on these runs is accounted for by the fact that the run with the Delco system was made with the spark fully retarded, while the run with the Dixie system was made with the spark fully advanced. During the one-hour runs at full power, none of the plugs ceased firing with either system, the oil merely burning on the plugs to form carbon. The resultant carbon deposits were about the same with either system. The power runs show that the magneto ignition gave a little bit more power both on the one-hour run and the run with set spark. To offset this, however, it should be noted that on the last power run with the battery ignition and spark set at each speed the power obtained was much higher than that which was obtained on any previous run, either with magneto or battery ignition. It is therefore concluded that spark plug fouling and power output is the same for both systems, within the limits of experimental error —*Air Service Information Circular*

The Crawford Sport Plane

The Crawford single seater sport plane was designed primarily to see if a machine of small dimensions could be built that would be stable enough for the average pilot. It proved out very well, being exceptionally stable, though very sensitive, to the controls. The get-away is surprisingly rapid, owing to the high thrust of 400 lb, compared to the loaded weight of 650 lb This takes the machine into the air at from 50 to 100 ft.

The general dimensions are span, 19 ft.; chord, 4 ft., overall length, 14½ ft.; weight, 500 lb, power plant, 50 hp

REAR VIEW OF THE CRAWFORD SPORT PLANE, FITTED WITH A 50 HP. GYROMOTOR

Gyro (rotary) motor; wing loading, 5 lb per sq ft, power loading, 13 lb per hp., high speed, 100 m p h, landing speed, 40-45 m p.h., the top plane is set at a 4 deg angle and the lower at 3½ deg incidence The top plane is set straight and the lower at a 2 deg dihedral. The stagger is 19 in Climb, 1,400 ft a min

The sides of the fuselage and the bottom to the back of the pilot's seat is covered with three ply birch veneer, doing away with cross wiring in these sections as well as forming the floor

The wing curve is a slightly altered U S A. 4. The beams are of spruce, ribs of 3/16 in, three ply birch Factor of safety in wings and wiring 20 to 1 All struts are of steel tubing, as well as the landing gear, which is rigid and fitted with 20 x 4 wheels and tires Control is of Dep type. Tail skid is a leaf spring, fastened at the stern post—also a steel tube.

The Crawford sport plane has attracted a great deal of attention and draws a crowd whenever it appears on the field It will not be put on the market but will be used solely for exhibition work, as the rotary motor which does not throttle, is not advisable for a sporting plane.

Its constructors, the Crawford Airplane Co., of Venice, Cal, are at present designing a slightly smaller and lighter plane, which will be fitted with a 2-cyl. V motor of 25 hp The designer of this new machine, C O. Prest, has been in aviation since 1810, having flown nearly all of the early types as well as many of the modern machines, and has designed and constructed a number of successful ships.

$1,250,000 for Air Mail Service

The Post Office appropriation for the fiscal year 1920-21, as finally approved by Congress, provides $1,250,000 for the Air Mail Service. This sum will permit the establishing of an air mail line between New York and San Francisco, via Chicago and Omaha.

Notes on Major Schroeder's Altitude Flight *

Major Schroeder's successful altitude flight was the result of a long series of important tests in engineering development by the Engineering Division, Air Service This series of tests have disclosed problem after problem which had to be overcome in some manner before further advances could be made. Some of these troubles were:

Difficulty of cooling at high altitude and of raising the boiling point of water

The problem of providing a drain valve to let the water out of the radiator at high altitude in case the engine stopped, so that the engine and cooling system would not be ruined by the water freezing and, at the same time, it was necessary for this valve to be arranged so that it would not itself freeze, thus making it impossible to operate it.

Major Schroeder had to invent and design special goggles which would not freeze over, in the intense cold at these great heights.

A special instrument had to be developed to show the pilot how to handle his exhaust bypass gates, or, in other words, how to control the supercharger pressure in his carburetors without the need of making any calculations.

The Engineering Division has been most fortunate in having Major Schroeder to pilot the airplane throughout the supercharger development tests because he is, in addition to being a surpassingly good pilot, an excellent engine mechanic and is one of the few pilots who can really sit in an airplane and know what an engine is doing and what it needs, and, in this way, he has helped the development immensely

Considerable trouble has always been encountered from pre-ignition when running with a supercharger, due to the fact that the air delivered to the carburetor is at very high temperature Future designs of superchargers will provide additional inter cooling between the compressor and the carburetors. The fuel feed system had, prior to Major Schroeder's record flight, operated quite satisfactorily but, in spite of this fact, it was necessary for Major Schroeder to close the vents in his gasoline tank and pump some pressure in them with a hand air pump in order to help the fuel pumps deliver the fuel at the extreme altitudes.

To reduce the pre-ignition which it was expected would be encountered on this flight, a specially prepared fuel was provided by Thomas Midgely, Jr, who has been developing "anti-knock" fuels for Mr Kettering This fuel proved to be of great assistance in this flight as it caused the motor to run much more smoothly than it would otherwise have done

The supercharger used by Major Schroeder was the old original General Electric supercharger designed by Dr Sanford A. Moss and originally tested on Pike's Peak in 1918. Therefore it is not surprising that no good means had been provided for blowing off the exhaust gases which issue from the turbine, consequently throughout all flights, the exhaust gas had bothered the pilot to a certain extent, due to the fact that it sweeps past his face. No way has been found to date to entirely carry the exhaust clear of the occupants of the machine. On this record flight, it seems that the gases expanded more rapidly as they issued from the turbine in the thin air at great altitude and in even larger volume swept past the pilot's face and, judging from the doctor's report, it seems that the carbon-monoxide poisoning gave Schroeder more trouble than the lack of oxygen.

In military work, an automatic oxygen feed apparatus is provided for the pilot which regulates the amount of oxygen in proportion to altitude so that the pilot need not think of making any adjustments. Major Schroeder had been in the habit of using a simple rubber tube from the neck of the oxygen flask to his mask in such a manner that he could adjust the flow by hand as he has often had trouble with the oxygen freezing up and stopping at high altitudes. On his record flight he knew he would be up for a long time and desired to use the automatic apparatus as long as he could and believed it would work to about 29,000 ft. He therefore took one bottle of oxygen connected through the automatic oxygen feed and one connected direct. However he found that the automatic apparatus did not work at all and he therefore had to start using his emergency bottle at about 18,000 ft., and realized that it might run short but thought it would last long enough for him to accomplish his record However, probably due to the large amount of exhaust gas he was breathing, Major Schroeder had to use an excess amount of oxygen This, of course, resulted in his reaching the end of his supply sooner than he expected. It is believed that his sudden lapse into unconsciousness was due more to the poisoning from the exhaust than to the effect of the lack of oxygen.

It is an interesting fact that the instrument which shows the pilot what pressure his supercharger is delivering to the carburetor, showed a pressure something close to that of sea level even when he was at the highest point of the flight The operation of the supercharger was excellent throughout the flight and it was found to be in good condition afterward

Major Schroeder states that he actually reached warmer temperature at the top of his climb The coldest temperature recorded was about —67 deg Fahr, and two or three thousand feet higher, at the top of his climb, the temperature was 4 deg higher He encountered the usual strong west wind which has been in every case encountered at altitudes above 25,000 ft He believes the velocity of this wind to be close to 175 m p.h, judging by the rate at which it drifted his machine eastward even though he was headed west and climbing at an extraordinarily high air speed, due to the use of the supercharger It is regretted that figures on these speeds cannot be given for publication.

It is an interesting fact that after a certain low temperature is reached, the exhaust gases issuing from the engine became snow white from the freezing of the vapor in it and from that time on, long white clouds formed by this exhaust are visible from the ground on a clear day such as the day on which Major Schroeder's flight was made This results in ice forming on all the wires and struts coming in contact with the stream of the exhaust.

Failure of Oxygen Supply

When Major Schroeder's oxygen supply finally failed, he raised his goggles in order to see more clearly to try and "coax" some more oxygen from one or the other of his tanks and at this moment, unconsciousness suddenly overtook him but not before he reached for his switch and put the machine into a spiral He intended to make one steep spiral which would bring him down to about 20,000 feet above the ground, where he expected to recover, but, although he believed after his fall that he had succeeded in doing this, as a matter of fact, the plane fell like a shot pigeon down to about 3,000 ft above the ground, where Schroeder regained consciousness, righted the plane and although he was still semi-unconscious and could scarcely see at all due to the chilling of his eyes, he had the presence of mind to open the vents in his gasoline tanks so that the engine would continue to get fuel and run. It happened that he succeeded in getting only one switch instead of two, which are present in all Liberty ignition systems, therefore his engine had been running practically wide open throughout this fall. This kept the water from freezing in the cooling system and gave him the use of the engine after his recovery from the fall.

The daily papers have been giving the details of his marvelous landing in spite of his almost total blindness, so nothing will be said here about that. However, it is of interest to note that the gasoline tanks which probably had a plus pressure of several pounds in relation to the surrounding atmosphere at the top of the climb, had collapsed, that is, three out of four of them had collapsed, one of them almost totally due to the fact that at the bottom of the fall, conditions had changed so that there was a minus pressure inside of several pounds. This is why it was necessary for Major Schroeder to open the vents in the tanks in order to be able to deliver fuel to the engine to get to a suitable place to land.

The military value of the supercharger will be very great It will greatly increase the speed of airplanes at altitudes, enable them to go much faster than they can near the ground. It will not be useful for extreme high altitude photography because the photographer will not be hampered by attack if the plane goes high enough. An airplane with supercharged en-

* Issued by Engineering Division, Air Service

gine will be valuable to carry dispatches or a high ranking officer over great distances in a very short time. Superchargers, when applied to heavy bombers, will enable this type of machine to reach a ceiling well above enemy anti-aircraft gun fire and in fighting planes, superchargers will greatly increase speed and climb.

Commercial use of superchargers will be to enable heavy passenger or express-carrying airplanes to climb over the highest mountains or over thunder storms with the use of comparatively low powered and low priced engines, without the supercharger very large engines would have to be installed in order to have sufficient power to sustain the airplane at high altitudes. This is largely unnecessary if superchargers are used. It is felt that passenger-carrying airplanes can be provided with a supercharger and an air-tight cabin for the passengers so that the supercharger can keep the air in this cabin at a density and temperature which will make it practically comfortable for all passengers, and, at the same time, the airplane can fly at extreme altitudes at very much greater speeds and speed, after all, is one of the chief advantages of air travel over other kinds.

Relative Merits of Biplane and Triplane Wing Structures*

Considerable differences exist in the types of wing structures adopted by airplane designers, these differences involve the actual number of planes, their plan form, aspect ratio, and section, the arrangement of bracing and the form and disposition of their control surfaces.

While the arrangement of these variables is comparatively simple from an aerodynamic point of view, structural considerations complicate matters.

It is proposed here to consider only the actual number of the lifting surfaces, and more particularly biplane and triplane systems, as the monoplane has rather a limited field, while it is extremely doubtful whether multi-planes having more than three planes will ever be required.

In considering the relative merits of monoplane, biplane, and triplane wing structures, it must be realized at the outset that no one of these wing arrangements will be suitable for all sizes and classes of machines.

Some of the advantages and disadvantages of the various types are perfectly definite, while others, especially when the machine is intended for commercial purposes, are more uncertain and depend largely upon the size, particular use to which the machine is put, country over which it operates, and the shedding accommodation or cargo space. The question then arises as to which wing arrangement is most suitable.

Considering, as a starting point, a two-seater fighting machine, having an overall weight of, say, 2000 lb., a power loading of 9.5 lb. per hp. and a wing loading of 8 lb. per sq. ft., it would be found that approximately similar performance could be obtained with either a monoplane, or biplane, wing structure. Lateral handiness would not be much different, as the aspect ratio of the monoplane could be reduced owing to its superior wing efficiency, any difference being in favor of the biplane.

If a machine of similar type and overall weight be designed for commercial work, the power loading would probably be about 15 lb. per hp. and the wing loading 9.5 lb. per sq. ft. This case would certainly call for a biplane wing structure, as the wing weight and span would be excessive in the monoplane and its lateral control poor, while for an equal degree of longitudinal stability a larger tail would be necessary.† Some approximations as to the value of these differences are given later.

As the size of aircraft increases, the question of keeping down overall dimensions and obtaining adequate maneuverability becomes increasingly important and difficult of attainment. It is, of course, unnecessary to have the same handiness in a machine intended for commercial purposes as in a war machine, though this does not mean that it is not equally desirable.

It can be shown that if the scale of any wing structure be increased, keeping the aileron area the same fraction of the wing area and of similar shape, that the ratio, aileron torque/moment of inertia of wing structure (using the term "aileron torque" to express the turning moment about the axis of the machine due to a given angular movement of the machine) decreases. This is accentuated by the fact that the wing weight per square foot of surface increases with increase of scale.

A size of machine is therefore eventually reached which is very sluggish laterally and while this, as stated above, does not matter very much while actually flying, it is still necessary to have as much control as possible for landing purposes.

This variation in lateral control can perhaps best be indicated by comparing a monoplane, biplane, and triplane of equal lift and equal aspect ratio, assuming that ailerons of similar proportions are fitted to all wings, and that the lift co-efficients for monoplane, biplane and triplane are represented by 1, .9 and .8, respectively.

It is found that the following values approximately hold:

Wing span.. Monoplane 1, Biplane .745, Triplane .646
Moment of inertia Monoplane 1, Biplane .6 , Triplane .51
Aileron torque Monoplane 1, Biplane 1.1 ; Triplane 1.25
Aileron torque/Moment of inertia Monoplane 1, Biplane 1.83, Triplane 2.48

Thus a triplane has considerably smaller overall dimensions and much greater lateral control. Also for a given amount of longitudinal stability the triplane will require a smaller tail area than the biplane (actually about 75 per cent of the area), or, conversely, for equal tail areas, a shorter fuselage will suffice.

Considered from a structural and production point of view, the question becomes considerably more complicated.

Without going into small details, it is fairly obvious that the biplane scores in the following points:

(A) Fewer separate parts.
(B) Simplified erection.
(C) Lower cost resulted from (A) and (B).
(D) Slightly lower wing weight in the smaller sizes.
(E) Slightly more efficient wings.
(F) Rather better view in the usual tractor machine.

The points in favor of the triplane are:

(G) Lower weight of wing structure in the larger sizes.
(H) Considerably reduced overall dimensions (except height).
(I) Considerably greater lateral control.

Point (A) to certain extent does not hold in larger sizes owing to the greater number of similar parts that obtain in a triplane, and owing to the fact that questions of transport limit the size of individual planes.

(C) follows (A).

(F) is of no importance in multi-engined machines.

It therefore seems that the tendency would be, and as a matter of fact is, for the smaller machines to be biplanes, the larger triplanes, and that the latter is practically compulsory on the score of control and dimensions alone, even at the expense of some possible disadvantages in other directions.

It seems as though a biplane structure is more satisfactory than a monoplane for even the smallest single seater machines, especially if the upper wing is made considerably larger than the lower. It remains to attempt to give some indication as to where the dividing line occurs, although this line is rather indefinite.

It seems from current practice that machines up to about 12,000 lb. gross weight can be constructed which will give satisfactory performances, and having overall dimensions within measurable limits.

Over that size and up to any size at present or considered at all practicable, a triplane construction is, on the whole, better.

It is obviously difficult to decide what will prove to be most satisfactory for any given machine which is on the border line indicated without actually designing alternative machines, and, even then it may be necessary to build experimental machines to get a final decision.

* Submitted by the British and Colonial Aeroplane Co.
† Ed. Note.—It is suggested that there is possibility of further discussion of this statement. In fact, the whole article is perhaps too dogmatic in tone.

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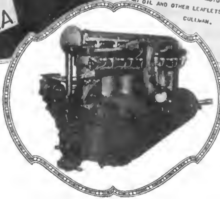

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